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The Geology and Production Characteristics of the Powder River and Other CBM Basins in Wyoming

Lance Cook

is set in place. Downside is that there are a lot of roads associated with coalbed methane development, which disrupts the wildlife habitat.

There is some increased pressure on threatened and endangered species and increased human contact with wildlife. And there are some issues with the spread of noxious weeds overtaking native growth. The agricultural industry—for some ranchers it's just been a blessing. They've seen some water improvements for stock and irrigation and seen an increase in personal income. On the downside of this, for other ranchers, the development has intruded on their ranching operations and they feel a loss of privacy and a change in their lifestyle. A change in things for the reasons they live out there and the things they do, their day-to-day lives.

And finally, socioeconomic impacts. It's lots of money. Wyoming is very much based on mineral production which includes coalbed methane. These mineral extractions have brought the majority of the revenue into communities in the state and Wyoming, and it provides education and other services that the state needs. It also, in the local areas such as the town of Gillette, which is the hub for minerals, brings people in and money in and obviously creates jobs. The downside is that it has created rapid population growth. The community is unable to keep up with some infrastructure demands, such as maintaining county roads due to increased traffic, even the roads in town. There are problems providing room in schools, hospitals, housing, and lodging. From what I understand, it's difficult to find a motel room up there, because a lot of people coming into town to work, that's where they stay. So room is limited in motels and also the "cross-bar" motel—the jail. Transient population—people are there for a certain period of time. They come and go. When their job is over, they leave. Increase in crime, increase in people, people having to live in adverse conditions. There are also issues with safety of some of their workers.

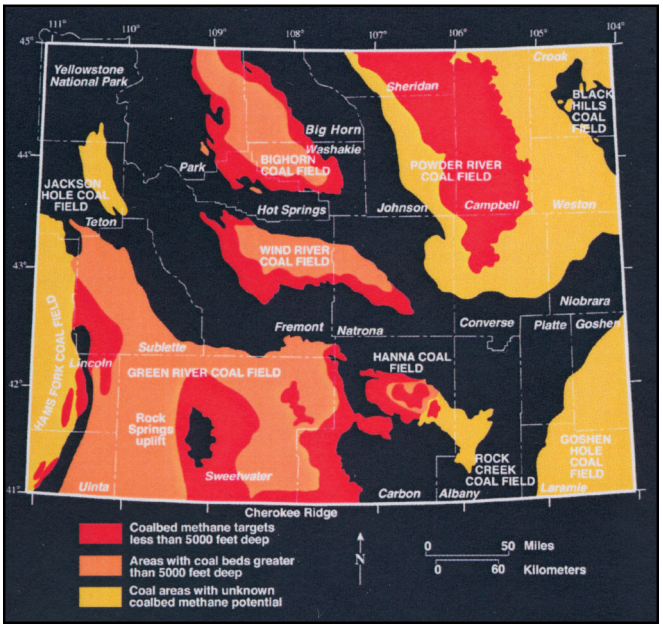
That is just a broad overview to set the stage. Our speakers will give a lot more detail on each of these issues.

THE GEOLOGY AND PRODUCTION CHARACTERISTICS OF THE POWDER RIVER AND OTHER CBM BASINS IN WYOMING

LANCE COOK, *Wyoming State Geologist*

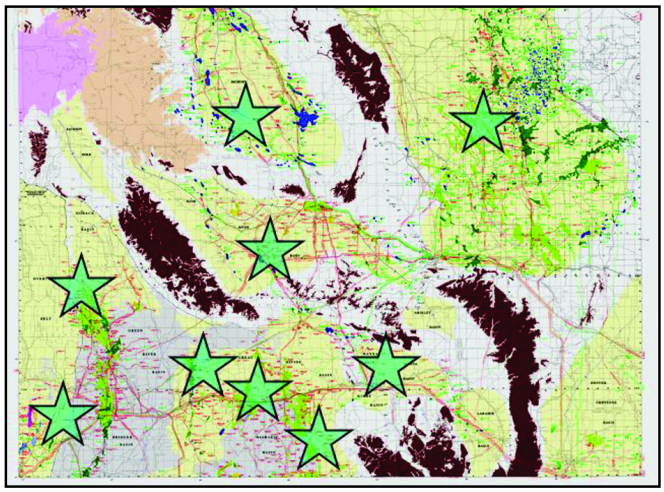
Good morning. Thank you for the opportunity to be here. I'm going to talk more about the subsurface than anything else and try and give you an idea of what the geology and the production characteristics of the coalbed methane reservoirs in Wyoming are like. And I'll do a little bit of comparison and contrast with what's been described in the San Juan Basin from yesterday. So we'll talk about where coalbed methane may occur in the state of Wyoming. We'll take a look a little bit at some of the Powder River Basin geology and the production characteristics. And we'll talk a little bit about this strange gas reservoir that seems to occur in conjunction with an aquifer.

This is a slide showing coalbed methane potential around the state of Wyoming. The Powder River Basin, as you see here, is a large area. This is coalbed methane production shallower than 5,000 feet. The coalbed methane areas with beds greater than 5,000 feet are shown here. And the areas with unknown coalbed methane potential are in these areas here.

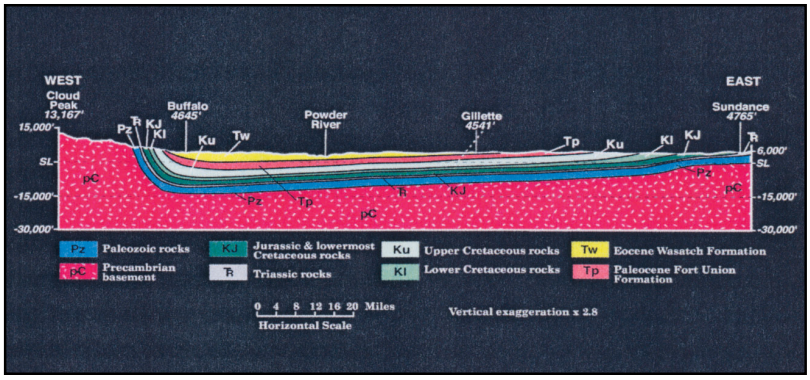


The next slide shows where the potential is outside of the Powder River Basin. There are a couple of projects going on right now. We have the Atlantic Rim, where there's an environmental impact statement going on right now. The vision is about 3,800 wells or 3,000 wells, something in that neighborhood. There's some private projects being drilled in that area, and we should have some results this summer or fall from those reports. We show coalbed methane potential in the Wamsutter Arch areas in the upper Cretaceous coals, and potential off to the north and to the lower corners. We have had a coalbed methane pilot project in the overthrust. I just heard the other day that that looks like it's probably going to be unsuccessful. No big surprise there. The geology is very complex in that area, and the area is pretty small. There's a pilot project going on at Big Piney, and some of the wells were drilled there this fall and winter. And there will be some initial drilling this spring and they'll get into production this summer. We have some projects going on in the Wind River Basin, and we have potential in the Big Horn Basin, being one of the larger unknowns right now. There is a coal field in the Big Horn Basin. Nobody's really done any work on it yet. People have looked at it and studies are being done, but nothing is publicly available right now.

HIGH CBM POTENTIAL AREAS

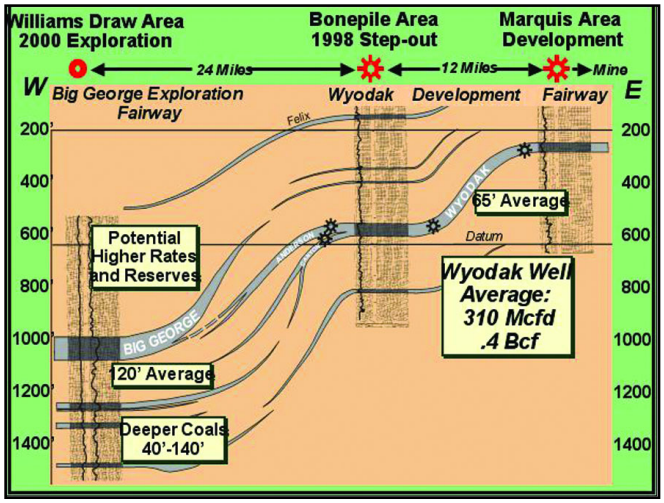


Next is a cross section, east to west across the Powder River Basin. The Powder River Basin is an asymmetric basin. There's a little bit more complexity on the west side. There's a thrust fault that brims the Big Horn Range on the west side and creates thrust faults. The coal section that produces in the Powder River Basin is in the Fort Union formation. It's in the brown or tan color here. So it crops out just to the east of Gillette. We have coal at the surface. It dips steadily into the basin at about one to one and a half degrees. We have the basin low or syncline just in front of the Big Horn Mountains, and then the beds dip up steeply to the surface. We've had development primarily in the shallow areas just alongside and west of the outcrop. And we've had development over on the west side of the basin, just east of the outcrop. We have had little development thus far in the deeper part of the basin, although we know that's where most of the impact probably is, in the deeper part of the basin.



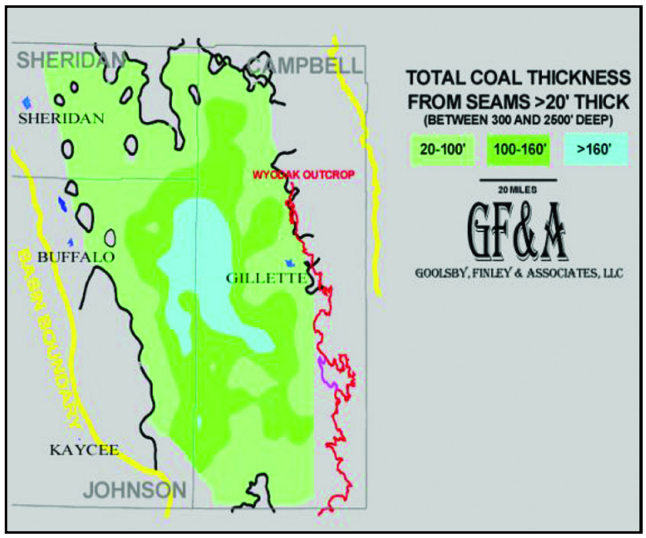
This is a schematic cross-section across part of the basin running from an area very close to the coal mines that were in the Marquis area. Here is one of the first areas that was developed in the basin, going to the Campbell/Johnson County line. This is called the Big George area. There are coal seams in the range of 100 to 200 feet in thickness, single coal seams. It's a very lucrative area in terms of a gas resource. In between, you can see the Bonepile Area, which was drilled in '98 and represented about a 12 mile step-out from the original development that we had. The Wyodak coal in here does not connect, you'll notice, to the Big George. We know that the Big George is set geologically higher than the rock columns of the Wyodak coals. So what we have is a series of major coal seams in the basin that are thick and fairly continuous over several miles, but they are not connected, necessarily, to other coal seams deeper in the basin.

COALBED METHANE STRUCTURAL CROSS SECTION POWDER RIVER BASIN



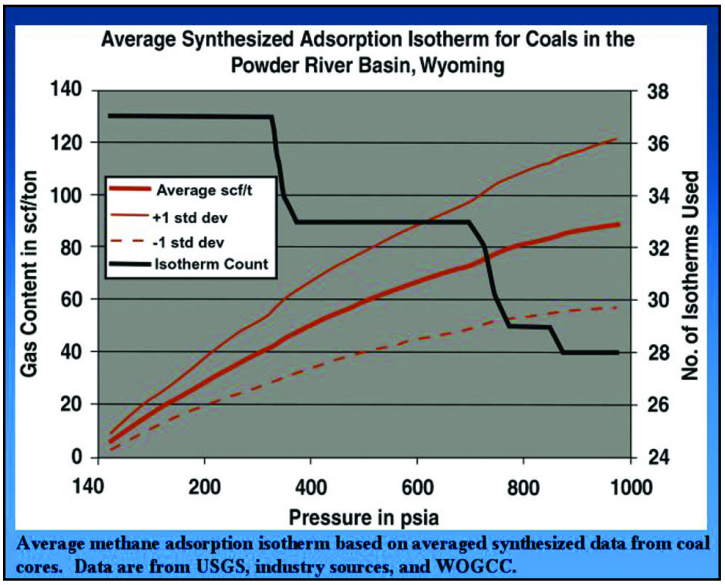
In the next slide, the blue color here represents aggregate coal seam thickness using coal seams greater than 20 feet thick. That's right here along the Johnson/Campbell County Line. That's the Big George area right there. This represents coal seam thickness greater than 160 feet of aggregated coal. And the darker green is 100 to 160 feet. And these lighter areas are 20 to 100 feet thick.

THICK COAL SEQUENCES



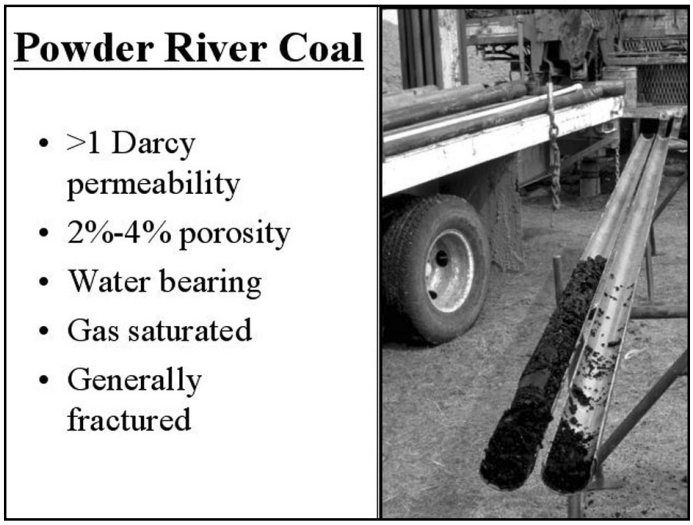
Powder River Basin coals are thick, but they have to be thick to make up for the fact that there's low saturation. The gas is stored in the coals via adsorption. This was touched on yesterday. The analogy in coalbed methane has been drawn that it's like popping the top on a bottle of soda, and that's really not right. It's an effective analogy, but it's not correct. The coal is physically located on the surface of a microfractured system called a cleat, and the process is called adsorption. It is the adherence of the gas molecules to the surface of the solids with which they are in contract. This is right out of the AGI glossary. So that gas is really physically situated on the surface of the fractures within the coal. Now, we go out in the industry, take a coal core, take it back to the laboratory and start to analyze that coal core to determine how much gas can that particular coal physically store on this microfractured surface. And that's what this curve shows.

This slide is about adsorption, or desorption, actually. Well, this is an adsorption isotherm for the coals in the Powder River Basin, using an aggregate of about 37 different cores from work around the basin. This is work done by, primarily, the USGS and the BLM. You can see a reservoir pressure of about 600 PSIA and about 65 cubic feet per ton. Those are low numbers. Typical San Juan Basin numbers are in the range of 300 to 400 standard cubic feet per ton. This makes up for its low gas content in thickness.



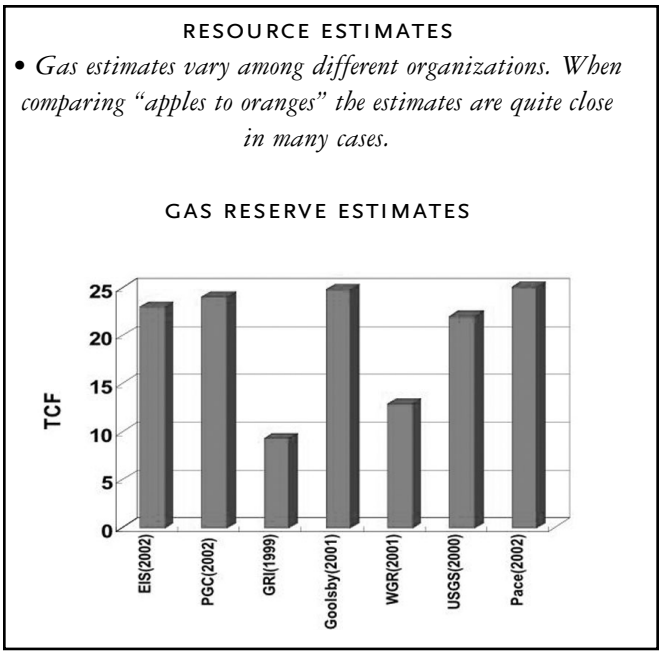
This is a photograph of a core as it comes out of the well. You can see that this is rubblized. It's heavily and intensively fractured. That's a very dominant characteristic of the Powder River Basin coals. Permeability in the coals is measured in terms of millidarcies. The coal in the Powder River Basin has greater than one darcy, or a thousand millidarcies of permeability. Yesterday you were hearing about a few millidarcies. In some cases, those

permeabilities have been shown to be over two darcies or 2,000 millidarcies. So we have huge permeability. That's what allows this low gas saturation in coal to produce gas. The coal is water-bearing. Once you get a mile or two away from the outcrop, the coal is saturated with water.



The coal is gas saturated. You saw that adsorption isotherm. That adsorption isotherm, once you know the reservoir pressure, accurately describes the amount of gas in the coal. If there were less gas in the coal, you would have to decrease the pressure even greater, and we don't find that to be the way. In almost all instances, the coal has as much gas stored in it as it can hold. That gas is biogenic gas, which is created by bacterial action. The coal is almost always fractured. There have been a few wells in the basin that did not tie into a fracture. Those are the exception. The rule is an average of about a darcy permeability.

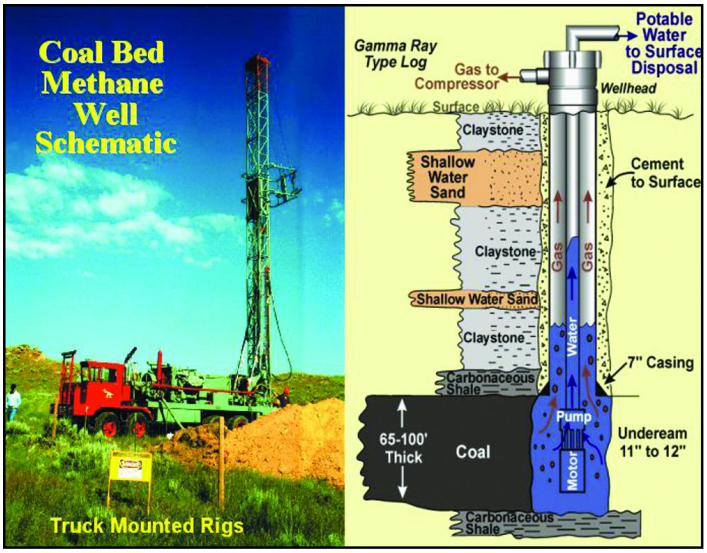
Resource estimates: In the early '90s, '91, '92, if we were only working on the basis of economically recoverable resources, the Powder River Basin would have been given zero dollars of gas value resources. That's not an accurate way to describe a resource. You have to go in and look at the resource in the ground and then trust human ingenuity and technology to get that resource. Nobody's smart enough to know all of the variables and all of the factors to say with certainty in the future whether a resource will be producible or not. We've gone from not having a recognized resource, economically, and we know in the Powder River Basin, we have somewhere between 20 and 25 trillion cubic feet of economically recoverable gas. The estimates that are lower were produced by the Gas Research Institute in 1999 who were not looking at a resource number. They were actually looking at a reserve number. Same with Western Gas Resources. They were looking at a slightly different measurement than we were. Pace Energy Services, U.S. Geological Survey, the Goolsby Study, Potential Gas Committee, and the BLM's Environmental Impact Statement where the resource estimate was done by their Reservoir Management Group, and all of them picked this number between 20 and 25 trillion cubic feet. The gas estimates vary, but they're very close. When the resource estimates are actually all looking at the same thing, they're very close together at around 25 TCF recoverable.



Well schematics: Wells are drilled differently in the basin. Surface casing is set and cemented in place. We go in, we under-ream for an open hole completion into a coal seam, and then we set a submersible pump and a simple sprayer to spray the water and the gas. It's a very low-technology completion, although there is some technology that goes into the monitors.

Gas production forecast: This is from a study that was recently done by Pace Global Energy Sources and is even more recent than the analysis that the BLM has put into their study. We're assuming a base price of $2.50 for gas, and we're at about 4.5 billion cubic feet a day. I still think that this is aggressive. I honestly think we're going to end up more in the range of three BCF per day, but we'll have to wait and see. Nobody's smart enough to predict future gas prices.

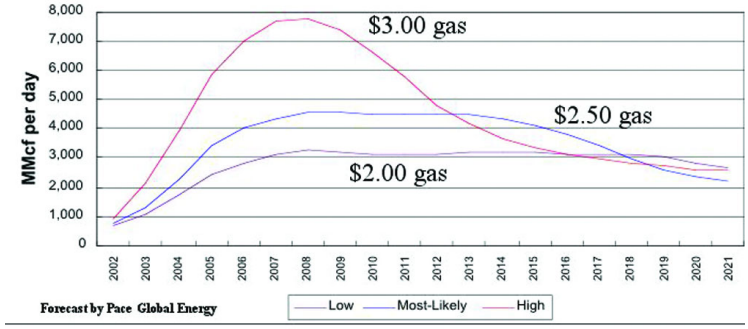
Reservoir simulation model: We saw some modeling work yesterday that showed nontypical coalbed methane curves. Some of those reservoir models were the early analysis done on data that was not appropriate for modeling. They were from wells that were unbounded. So you're basically trying to model an open system with widely differing well profiles in terms of water production and gas production. It's not until you aggregate a large number of wells that you're able to generate curves like this that fits the classical coalbed methane curves. So you have to work with them on a statistical basis.



GAS PRODUCTION

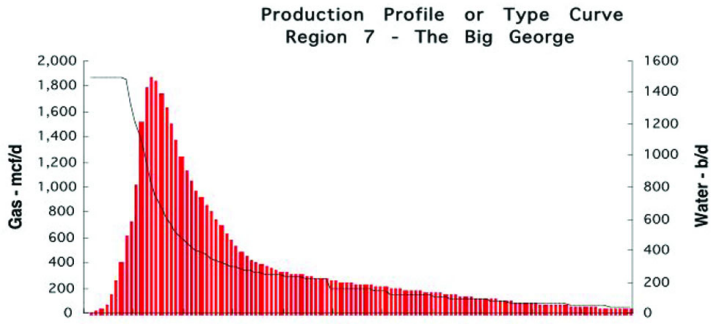
• *Gas production peaks at 4.6 Bcf/d in 2009 in the most likely scenario.*

CBM GAS PRODUCTION FORECASTS BY SCENARIO



RESERVOIR SIMULATION MODEL

- *While individual wells may have differing curves, well populations have well-defined production profiles.*

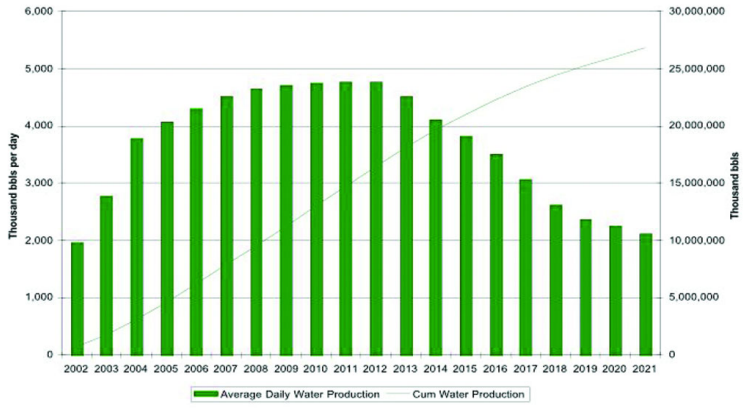


Cumulative water production: This is based on that medium-priced scenario that we saw on gas production. Cumulative water production here shows something in the range of 25 billion barrels per day estimated to be produced by the year 2021.

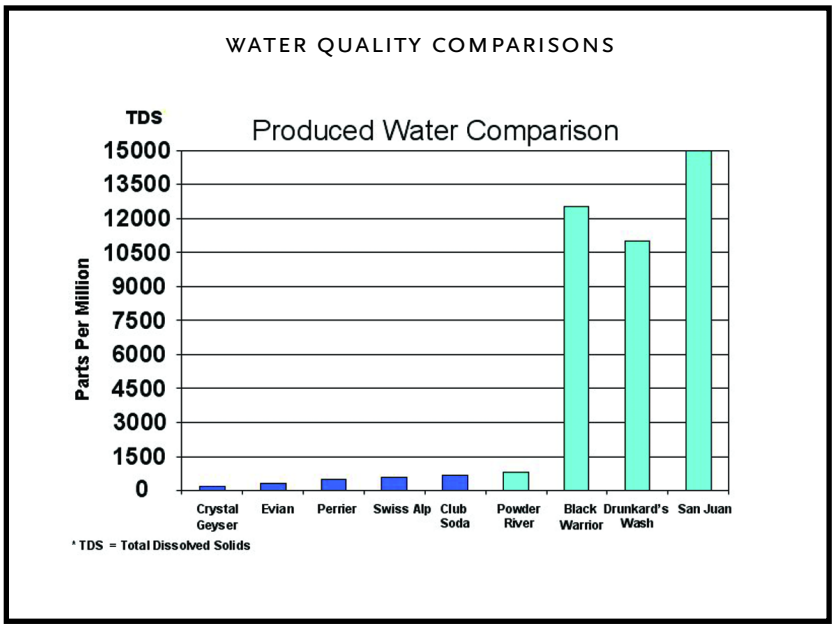
WATER PRODUCTION

- *The average water production per day per well is 150 barrels during a typical 7-year life.*

WATER PRODUCTION FOR ALL REGIONS "MOST LIKELY SCENARIO"



Finally, water quality comparison. I need to make something very clear and make sure you understand this. A lot of people refer to the produced water in the Powder River Basin as saline water. The Powder River Basin's coal water averages around 1,000 to 800 parts per million. As you move to the western parts of the basin, that number gets up close to 1,000 parts per million. Little bit less in some places, more in others. There's club soda and crystal geyser. By comparison, water is about 13,000 parts per million in the Black Warrior. Drunkard's Wash is about 11,000 parts per million. San Juan Basin, 15,000 parts per million.



This water is very different from other coalbed methane waters. It is low salinity. What it has is a peculiar chemistry. It is sodic water. A very high amount of the total dissolved solids in this water is due to sodium. We have almost no calcium and also no magnesium. It's because of that peculiar water chemistry, and only because of that, that we have a conflict between the use of the water for irrigation and the soil types. Clay-rich soils are probably about the worst kind of soil you can have for that. Nonetheless, this water meets drinking water standards, fit for human conception. And in many cases, the water is superior in quality coming out of the coal seams than it is for shallow water coming out of the Wasatch Formation. Thank you.

A REVIEW OF CBM DEVELOPMENT IN THE POWDER RIVER AND OTHER WYOMING BASINS

DON LIKWARZ, *Director, Wyoming State Oil and Gas Conservation Commission*

Thank you very much. I'm glad to be here this morning. We thought it would make more sense if Lance got up first and set the stage. I'll get into the details. I'm known as "Mr. Facts" because I have all the data. We have a really good web site that's updated on a daily basis electronically, so some of the data is brand new, and some of it is two or three weeks old. So it won't agree with some of the information you heard over the last few days. Again, I may be repeating some things, but I'm trying to make sure you come away with some of the key points.

As Lance said, this is totally different than any other large coalbed methane development taking place. It works because the depth of the coals is shallow. It starts at about 200 feet from the surface just west of those strip mines that were shown on some of the information this morning, and it's moving west at about two to three miles a year. And this is what we call the fairway. Where most of the producing wells are at right now is about 15 miles from the west—from the mines out about 15 miles west—and about 55 miles north to south. So about a 1,500 square mile area. We are now also moving northward to the Sheridan area where there are a couple of pilot projects going on, and then up along the Powder and Little Powder towards the Montana/Wyoming state line.

Most of the drilling, to date, probably averages about 950 feet deep. As a result, using the small truck-mounted